

522,471

(19) World Intellectual Property  
Organization  
International Bureau



(43) International Publication Date  
12 February 2004 (12.02.2004)

PCT

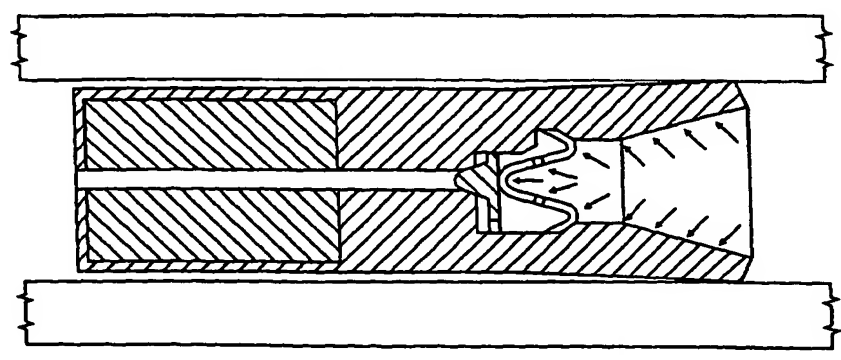
(10) International Publication Number  
**WO 2004/013530 A1**

- (51) International Patent Classification<sup>7</sup>: **F16L 7/02** Mens, Union Glen, Aberdeen, AB11 6FP, United Kingdom (GB).
- (21) International Application Number: PCT/EP2003/008115 (74) Agent: **MURGITROYD & COMPANY**; Scotland House, 165-169 Scotland Street, Glasgow G5 8PL (GB).
- (22) International Filing Date: 24 July 2003 (24.07.2003) (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 0217295.5 26 July 2002 (26.07.2002) GB (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
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**Published:**  
— with international search report

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: SEAL ASSEMBLY



(57) Abstract: A seal assembly for sealing an annular space between an inner and an outer pipe in a double-walled subsea pipeline which seal assembly comprises an annular member (1) and moveable blocking means (2, 3) and: (a) under normal operating conditions is in a non-sealing position which allows the passage of a gas through said seal assembly; and (b) is actuatable from a non-sealing position to a sealing position in response to the entry of liquid into said annular space.

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### Seal Assembly

1 The present invention relates to double-walled  
2 pipelines used for transporting fluids such as oil  
3 and gas. In particular it relates to a seal  
4 assembly for use in sealing an annular space between  
5 an inner pipe and an outer pipe in such a double-  
6 walled pipeline.

7  
8 Pipelines carrying heavy or crude oil need to be  
9 thermally insulated as heavy oil tends to solidify  
10 during transport from a subsea production well to  
11 the surface due to heat losses in the submerged  
12 pipeline. Thermal insulation is also required to  
13 avoid the formation of hydrates which can occur for  
14 certain crude oil compositions when the crude oil  
15 cools down, for example, when there is a breakdown  
16 in production flow rate.

17  
18 Production lines which require a high level of  
19 thermal insulation typically use a double-walled  
20 pipe structure, for example a pipe-in-pipe system.  
21 A pipe-in-pipe system comprises an internal pipe  
22 within an external pipe separated by an annulus

1 volume. In such a structure, the annular space can  
2 be filled with thermal insulation material. This  
3 structure has the advantage that the external pipe  
4 keeps the annular space dry and so, for example, in  
5 subsea pipelines, the thermal insulation material is  
6 protected from water. A further advantage of this  
7 structure is that the pressure in the annulus can be  
8 different from that outside the external pipe and  
9 that inside the internal pipe. This is important if  
10 the insulating material has a particular pressure  
11 requirement or if a vacuum or partial vacuum is to  
12 be used for insulating purposes. For example, the  
13 annulus can be at atmospheric pressure while the  
14 hydrostatic pressure experienced by the external (or  
15 carrier) pipe and the internal pressure of the fluid  
16 in the internal pipe (flowline) are different.  
17 Furthermore it is interesting to lower the pressure  
18 in the annulus in order to increase the thermal  
19 insulation performance.

20

21 One of the problems associated with such pipelines  
22 is that of safeguarding the annular space against  
23 the ingress of water, for example due to leaks in  
24 the external or carrier pipe. Water in the annular  
25 space will conduct heat from the inner flowline to  
26 the carrier pipe thus destroying the effectiveness  
27 of the insulation. This problem has been approached  
28 in prior art pipe-in-pipe systems by  
29 compartmentalising the annular space by means of  
30 permanent seals (GB 2 317 934, US 2 930 407, WO  
31 00/09926). It is desirable, in some cases, to have  
32 a vacuum or partial vacuum in the annular space.

1 When the annular space is compartmentalised by  
2 permanent seals, the vacuum or partial vacuum in the  
3 annular space must be created during the manufacture  
4 of the double walled pipe. Once manufactured, it is  
5 then not possible to vary the pressure within the  
6 compartments, for example, so as to maintain the  
7 required pressure throughout the lifetime of the  
8 pipe. An ability to vary this pressure would be  
9 useful, for example, in the case of diffusion of  
10 gases into the annulus through the internal or  
11 external pipes or a leak which modifies the pressure  
12 within the compartment and alters the thermal  
13 insulation capabilities of the pipeline. There  
14 remains a need for a pipeline for which the pressure  
15 within the annular space can be controlled during  
16 the lifetime of the pipeline and a pipeline for  
17 which the annular space can be separated into  
18 compartments in the case of a leak of water or  
19 hydrocarbon fluids into the pipeline, thus  
20 preventing flooding of the whole annular space.  
21 The above problems are solved by the seal assembly  
22 of the present invention.

23

24 In accordance with the invention there is provided a  
25 seal assembly for sealing an annular space between  
26 an inner and an outer pipe in a double-walled subsea  
27 pipeline which seal assembly under normal operating  
28 conditions is in a non-sealing position which allows  
29 the passage of a gas through said seal assembly and  
30 which seal assembly is actuatable from a non-sealing  
31 position to a sealing position in response to the  
32 entry of liquid into said annular space.

1  
2 Preferably the seal assembly in its non-sealing  
3 position provides an opening in the annular space to  
4 allow the passage of a gas through the seal  
5 assembly. Preferably the seal assembly comprises an  
6 annular member and moveable blocking means such that  
7 entry of liquid into said annular space causes  
8 movement of said blocking means to close said  
9 opening.

10  
11 Preferably the blocking means is moveable under  
12 pressure of liquid flow or the seal assembly  
13 comprises a liquid-sensitive material and the  
14 blocking means is moveable as a result of  
15 interaction of the liquid with said liquid-sensitive  
16 material.

17  
18 Embodiments of the invention will now be described,  
19 by way of example only, with reference to the  
20 accompanying drawings in which:

21  
22 Figure 1a is a cross-sectional view of a seal  
23 assembly according to a first aspect of the present  
24 invention.

25  
26 Figures 1b and 1c are cross-sectional views of a  
27 seal assembly according to a first aspect of the  
28 present invention in non-sealing and sealing  
29 positions respectively.

30  
31 Figure 1d is a cross-sectional view of a closure  
32 member and a plan view of a closure member.

1

2 Figure 1e is a cross-sectional view of a diaphragm  
3 and a plan view of a diaphragm.

4

5 Figures 2a and 2b are perspective views of a valve  
6 for insertion into a seal assembly according to the  
7 second aspect of the present invention. In Figure  
8 2b, the valve is in its non-sealing position.

9

10 Figures 3a and 3b are cross-sectional views of a  
11 valve for insertion into a seal assembly according  
12 to the second aspect of the present invention, in  
13 non-sealing and sealing positions respectively.

14

15 Figures 3c and 3d are cross-sectional views of a  
16 valve for insertion into a seal assembly according  
17 to the second aspect of the present invention, in  
18 non-sealing and sealing positions respectively.

19

20 Figures 4a to 4d are cross-sectional views of a seal  
21 assembly according to the third aspect of the  
22 present invention. In Figures 4b and 4c, the seal  
23 assembly is in a non-sealing position in the annular  
24 space between an outer pipe and an inner pipe.

25

26 Referring now to the drawings Figure 1a shows a seal  
27 assembly according to a first aspect of the present  
28 invention. In the first aspect of the present  
29 invention the annular member (1) comprises one or  
30 more orifices (5) and the moveable blocking means  
31 comprises a diaphragm (2) and a closure member (4)  
32 such that flow of liquid in said annular space

1 causes movement of the diaphragm which causes  
2 movement of the closure member to close said one or  
3 more orifices.

4  
5 Preferably the annular member is capable of  
6 extending from the inner wall of the outer pipe to  
7 the outer wall of the inner pipe and of being in  
8 sealing contact with each of said inner and outer  
9 walls. By sealing contact is meant that the passage  
10 of gas or liquid through the contact interface is  
11 not possible. This is achieved by the appropriate  
12 dimensioning of the annular member. Figures 1b and  
13 1c show the annular member in sealing contact with  
14 each of the inner and outer walls of the annular  
15 space in a pipe-in-pipe structure. Preferably the  
16 annular member is made from a rubber material or an  
17 elastomeric material, for example polyurethane. The  
18 annular member may comprise a steel insert (4) for  
19 strengthening/rigidity purposes.

20  
21 Preferably the annular member has a longitudinal end  
22 face which is recessed i.e., it has a concave cross-  
23 section defining upper and lower arms. Upper and  
24 lower relate to the larger circumference and the  
25 smaller circumference sides which define the end  
26 face of the annular member, respectively.

27 Preferably, the larger diameter of the recessed end  
28 face is larger than that of the outer pipe and the  
29 smaller diameter of the recessed end face is smaller  
30 than that of the inner pipe of the pipe-in-pipe  
31 structure in which the annular member is to be used.  
32 This is so that in order to fit into the annular

1 space, the annular member must be compressed at the  
2 recessed end. Once inserted into the annular space,  
3 the recessed end will try to expand, thus wedging  
4 the annular member in place.

5

6 Figure 1b shows a cross-section of the above seal  
7 assembly in an annular space between inner and outer  
8 pipes in a non-sealing position. In this non-  
9 sealing position, gas can pass through the seal  
10 assembly via apertures (6,7) in the diaphragm, via a  
11 gap between the annular member and the closure  
12 member and via orifice (5) in the annular member.  
13 The annular member may have one or more orifices;  
14 the number and size of which will depend on  
15 application parameters, for example, the dimensions  
16 of the inner and outer pipes, the repartition of the  
17 waterstops along the pipeline, the length of the  
18 pipeline, the sensitivity of the moveable blocking  
19 means.

20

21 In this embodiment, both the diaphragm and the  
22 closure member are moveable. Preferably the closure  
23 member is annular in shape as can be seen from the  
24 embodiment shown in Figure 1d. In the embodiment  
25 where the annular member has a longitudinal end face  
26 which comprises a concave cross-section defining  
27 upper and lower arms, the closure member may be  
28 attached by resilient means to one of the upper and  
29 lower arms of the annular member. Preferably there  
30 is a gap between the closure member and the other  
31 arm of the annular member to allow flow of gas past  
32 the closure member when the seal assembly is in a

1 non-sealing position. The closure member may  
2 comprise protrusions (8) positioned on the closure  
3 member so that they correspond in position to the  
4 one or more orifices in the annular member that they  
5 are intended to plug. The protrusions are shaped so  
6 that when pressed against an orifice they will form  
7 an effective seal.

8  
9 Preferably the diaphragm is annular in shape as can  
10 be seen from the embodiment shown in Figure 1e. In  
11 the embodiment where the annular member has a  
12 longitudinal end face which comprises a concave  
13 cross-section defining upper and lower arms, the  
14 diaphragm may extend between the upper and lower  
15 arms of the annular member and comprise apertures to  
16 allow flow of gas through the diaphragm when the  
17 seal assembly is in a non-sealing position. The  
18 diaphragm may be buckled in shape to increase the  
19 efficiency of its function as shown in Figure 1e.

20  
21 Preferably both the diaphragm and the closure member  
22 are annular in shape. In a preferred embodiment,  
23 the annular member has a longitudinal end face which  
24 comprises a concave cross-section defining upper and  
25 lower arms; the closure member is attached by  
26 resilient means to one of said upper and lower arms;  
27 and the diaphragm extends between said upper and  
28 lower arms.

29  
30 Under normal operating conditions, i.e., when the  
31 pipeline is not leaking and there is no ingress of  
32 liquid into the annular space, the seal assembly is

1 in its non-sealing position. Should liquid leak  
2 into the annular space, the flow of liquid in the  
3 annular space causes movement of the diaphragm which  
4 causes movement of the closure member, which in turn  
5 closes the one or more orifices. Preferably the  
6 pressure of the liquid acts directly on the  
7 diaphragm causing the diaphragm to press against the  
8 closure member causing the closure member to move  
9 into a position where it closes the one or more  
10 orifices. The apertures in the diaphragm are closed  
11 on contact with the closure member. The seal  
12 assembly in its sealing position is shown in Figure  
13 1c. The direction of liquid flow is indicated by the  
14 arrows. In this first aspect of the invention, the  
15 liquid must flow towards the diaphragm to actuate  
16 the seal assembly from a non-sealing position to a  
17 sealing position.

18  
19 In a second aspect of the present invention the  
20 annular member comprises one or more valves and said  
21 valves each comprise one or more orifices and  
22 moveable blocking means such that the flow of liquid  
23 in said annular space causes movement of the  
24 moveable blocking means to close said one or more  
25 orifices.

26  
27 A valve comprises one or more orifices and moveable  
28 blocking means. Figures 2 and 3 show embodiments of  
29 valves according to this aspect of the invention.  
30 The valve may comprise a housing which has one or  
31 more orifices and which houses the moveable blocking  
32 means. The valve may also be connected to tubing or

1     hosing. The tubing or hosing may form an integral  
2     part of the housing. The valve may be situated  
3     within the tubing or hosing. The one or more valves  
4     may be attached to or form part of the annular  
5     member. Preferably the valve (and, if present,  
6     tubing) is insertable into the annular member.  
7     Preferably the annular member comprises one or more  
8     tubes in which tubes the one or more valves are  
9     situated.

10

11    In this second aspect of the invention the valve may  
12    be located on either face of the annular member,  
13    i.e., either on the face that confronts the flow of  
14    liquid or on the opposite face.

15

16    Figure 2a shows a valve (9) and tubing (10)  
17    arrangement that can be inserted into the annular  
18    member. In this embodiment of the second aspect of ..  
19    the present invention a valve comprises a blocking  
20    plate (16) with an orifice and the moveable blocking  
21    means comprises a diaphragm (14) and a closure  
22    member (12) which closure member has apertures (15)  
23    such that flow of liquid in the annular space causes  
24    movement of the diaphragm which causes movement of  
25    the closure member against the blocking plate  
26    closing the orifice in the blocking plate and the  
27    apertures in the closure member. The valve  
28    comprises a housing (11) in the shape of a truncated  
29    cone and this may be located at the end of tubing.  
30    A membrane or diaphragm that is permeable to gas but  
31    not liquid covers the end of the housing having the  
32    larger diameter. The end of the housing having the

1 smaller diameter (the nose) of the housing is formed  
2 by a blocking plate or ring (16) which has an  
3 orifice in it. In this embodiment the closure member  
4 comprises a plug having the shape of a truncated  
5 cone (13) which fits in a sleeve-like fashion into  
6 the housing. The nose of the plug has orifices in  
7 it. A retaining nut (17) holds the conical plug in  
8 place inside the housing in a preloaded position so  
9 that the nose of the plug is at a distance from the  
10 blocking plate or ring. This is the non-sealing  
11 position and is shown in Figure 2b. When there is  
12 sufficient pressure of liquid on the membrane, the  
13 membrane will push on the conical plug so that it  
14 comes into contact with blocking plate and closes  
15 off the orifices.

16  
17 Preferably the diaphragm is made of Gortex  
18 (trademark) and preferably the rest of the moveable  
19 means is made of a rubber type material. Silicone  
20 grease may be used during assembly on all sliding  
21 faces.

22  
23 In this embodiment the valve may be located on  
24 either face of the annular member, i.e., either on  
25 the face that confronts the flow of liquid or on the  
26 opposite face. In either location the direction of  
27 the flow of liquid should be such that it confronts  
28 the diaphragm before the blocking plate.

29  
30 Figure 3 shows two further embodiments of a valve  
31 according to the second aspect of the present  
32 invention. In these embodiments the moveable

1 blocking means comprises biased means attached to a  
2 closure member which biased means is held in a  
3 biased position by means of a liquid-sensitive  
4 material such that the presence of liquid in said  
5 annular space causes interaction of said liquid with  
6 said liquid-sensitive material causing said liquid-  
7 sensitive material to release the biased means so  
8 that said biased means effects movement of the  
9 closure member to close said one or more orifices.

10

11 Figure 3a shows valve (18) in a non-sealing position  
12 which comprises housing (19), orifices (20, 21) and  
13 tubing (22). In this embodiment the valve housing  
14 is in the shape of truncated tubing and has orifices  
15 in the side walls as is shown in Figures 3a and b.  
16 The moveable blocking means comprises biased means  
17 (23) attached to a closure member (24). The biased  
18 means may be either a compression or a tension  
19 spring, preferably the biased means is a tension  
20 spring. The biased means is held in a biased  
21 position, for example a spring held in a compressed  
22 state, by means of liquid-sensitive material (25).  
23 Interaction with liquid in the annular space causes  
24 the liquid-sensitive material to react or dissolve  
25 thus releasing the biased means. Release of the  
26 biased means causes movement of the closure member  
27 into a position where it closes off the one or more  
28 orifices in the valve head. The valve in its  
29 sealing or closed-off position is shown in Figure  
30 3b. Preferably, in this embodiment the valve is  
31 located on the face of the annular member that  
32 confronts the flow of liquid.

1

2 Figures 3c and d show a further embodiment of a  
3 valve for insertion into a seal assembly according  
4 to the present invention, in non-sealing and sealing  
5 positions respectively. Figure 3c shows valve (18)  
6 which comprises housing (19), orifices (20, 21) and  
7 tubing (22). The moveable means comprises a biased  
8 spring (23) and closure member (24). The spring is  
9 held in a compressed state by means of a retaining  
10 wire (26) which is restrained in position by a  
11 liquid-sensitive material (25). When liquid enters  
12 the annulus the liquid sensitive material will react  
13 or dissolve on contact with the liquid, releasing  
14 the retaining wire and simultaneously releasing the  
15 spring. On release, the spring pushes closure  
16 member (24) to close off the orifices (see Figure  
17 3d).

18

19 Preferably the liquid-sensitive material is a salt  
20 that will dissolve or partially dissolve on contact  
21 with the liquid or an absorbent material that will  
22 soften on contact with the liquid.

23

24 In a third aspect of the present invention the  
25 annular member is dimensioned so that it will be in  
26 sealing contact with only one of the inner wall of  
27 the outer pipe and the outer wall of the inner pipe  
28 and will provide an opening in said annular space  
29 between the annular member and the wall with which  
30 it is not in sealing contact and the moveable  
31 blocking means comprises resilient means which is

1 deformable under the pressure of liquid flow in the  
2 annular space to close said opening.

3

4 An embodiment according to this aspect of the  
5 invention is shown in Figure 4. The seal assembly  
6 of Figure 4 comprises an annular member (27) and  
7 moveable blocking means (28). Figures 4a and 4b  
8 show the seal assembly in a non-sealing position in  
9 a pipe-in-pipe structure. The annular member is  
10 capable of being in sealing contact with only one of  
11 the inner wall of the outer pipe (31) and the outer  
12 wall of the inner pipe (32) thus providing an  
13 opening (33) in said annular space (30) between the  
14 annular member and the wall with which it is not in  
15 sealing contact. This is achieved by the  
16 appropriate dimensioning of the annular member.  
17 Preferably the annular member is capable of being in  
18 sealing contact with only the outer wall of the  
19 inner pipe.

20

21 In this aspect of the invention the moveable member  
22 comprises resilient means which is deformable under  
23 the pressure of liquid flow. The moveable member  
24 may be a lip on the annular member. Preferably the  
25 annular member and the moveable member are made from  
26 the same material. Preferably the annular member  
27 has a longitudinal end face which comprises a  
28 concave cross-section defining (or has a recess  
29 which defines) upper (28) and lower (34) arms and  
30 one of these arms is the resilient means deformable  
31 under the pressure of liquid flow in the annular  
32 space. Upper and lower relate to the larger

1 circumference and the smaller circumference sides  
2 which define the end face, respectively. Preferably  
3 the lower arm is in sealing contact with the upper  
4 wall of the inner pipe. In this embodiment the  
5 upper arm is the resilient means moveable under the  
6 pressure of liquid flow.

7  
8 Preferably, the larger diameter of the end face is  
9 larger than that of the outer pipe and the smaller  
10 diameter of the end face is smaller than that of the  
11 inner pipe of the pipe-in-pipe arrangement in which  
12 the annular member is to be used. This is so that  
13 in order to fit into the annular space, the annular  
14 member must be clamped closed and held in this  
15 position by an annular restraining means (35). The  
16 annular restraining means has a complementary shape  
17 to the concave recess in the end face of the annular  
18 member. Preferably the annular restraining means is  
19 bonded (36, 37) to the lower and upper arms  
20 respectively of the annular member, thus restraining  
21 them from moving apart. This bond may be made by a  
22 water-soluble glue/adhesive.

23  
24 In this third aspect of the invention the  
25 longitudinal end face having a recess confronts the  
26 flow of liquid. In operation, flow of liquid will  
27 exert force on this end face. The most vulnerable  
28 component of the seal assembly to this force is the  
29 upper arm (moveable means) and when the force is  
30 sufficient to break the bond between it and the  
31 annular restraining means, the upper arm is pushed

1     against the inner wall of the upper pipe thus  
2     effecting a seal (see Figure 4c).

3  
4     The present invention also provides a pipe system  
5     comprising an inner pipe and an outer pipe and a  
6     seal assembly selected from the seal assemblies  
7     described herein. Preferably the seal assemblies  
8     are installed in pairs in order to prevent the  
9     passage of liquid in both directions. The annular  
10    space in the pipe system may also comprise  
11    insulation material and/or one or more elements  
12    chosen from bulkheads to transfer loads (services or  
13    handling loads) between the carrier pipe and the  
14    flowline; spacers to centre the flowline within the  
15    carrier pipe; buckle arrestors to prevent the  
16    propagation of a buckle along the carrier pipe.  
17    Preferably the seal assemblies are installed near to  
18    buckle arrestors so that when buckle propagation is ..  
19    stopped, any water leak due to the buckle will not  
20    be allowed to proceed through the pipeline.

1           CLAIMS

2       1.    A seal assembly for sealing an annular space  
3            between an inner and an outer pipe in a double-  
4            walled subsea pipeline which seal assembly:

5            (a)   under normal operating conditions is in a  
6                non-sealing position which allows the  
7                passage of a gas through said seal  
8                assembly; and

9            (b)   is actuatable from a non-sealing position  
10           to a sealing position in response to the  
11           entry of liquid into said annular space.

12

13       2.   A seal assembly according to claim 1 which

14           (a)   in its non-sealing position provides an  
15                opening in the annular space to allow the  
16                passage of a gas through the seal  
17                assembly; and

18           (b)   comprises an annular member and moveable  
19                blocking means such that entry of liquid  
20                into said annular space causes movement of  
21                said blocking means to close said opening.

22

23       3.   A seal assembly according to claim 2 wherein  
24            the blocking means is moveable under pressure  
25            of liquid flow.

26

27       4.   A seal assembly according to claim 2 which  
28            comprises a liquid-sensitive material and  
29            wherein the blocking means is moveable as a  
30            result of interaction of the liquid with said  
31            liquid-sensitive material.

32

1       5. A seal assembly according to claim 3 wherein  
2           (a) the annular member comprises one or more  
3               orifices; and  
4           (b) the moveable blocking means comprises a  
5               diaphragm and a closure member such that  
6               flow of liquid in said annular space  
7               causes movement of the diaphragm which  
8               causes movement of the closure member to  
9               close said one or more orifices.

10

11       6 A seal assembly according to claim 5 wherein  
12           the diaphragm and closure member are both  
13           annular in shape.

14

15       7 A seal assembly according to any one of claims  
16           2 to 4 wherein:

17           (a) the annular member comprises one or more  
18               valves; and  
19           (b) said valves each comprising one or more  
20               orifices and moveable blocking means such  
21               that flow of liquid in said annular space  
22               causes movement of the moveable blocking  
23               means to close said one or more orifices.

24

25       8 A seal assembly according to claim 7 wherein a  
26           valve comprises a blocking plate with an  
27           orifice and the moveable blocking means  
28           comprises a diaphragm and a closure member  
29           which closure member has apertures such that  
30           flow of liquid in the annular space causes  
31           movement of the diaphragm which causes movement  
32           of the closure member against the blocking

1 plate closing the orifice in the blocking plate  
2 and the apertures in the closure member.  
3

4 9 A seal assembly according to claim 7 wherein  
5 the moveable blocking means comprises biased  
6 means attached to a closure member which biased  
7 means is held in a biased position by means of  
8 a liquid-sensitive material such that flow of  
9 liquid in said annular space causes interaction  
10 of said liquid with said liquid-sensitive  
11 material causing said liquid-sensitive material  
12 to release the biased means so that said biased  
13 means effects movement of the closure member to  
14 close said one or more orifices.  
15

16 10 A seal assembly according to claim 9 wherein  
17 the biased means is a spring.  
18

19 11 A seal assembly according to claim 9 or 10  
20 wherein the liquid-sensitive material is a  
21 water-soluble salt.  
22

23 12 A seal assembly according to any one of claims  
24 7 to 12 wherein the annular member comprises  
25 one or more tubes in which tubes the one or  
26 more valves are situated.  
27

28 13 A seal assembly according to any one of the  
29 preceding claims wherein the annular member is  
30 dimensioned so that it will extend from the  
31 inner wall of the outer pipe to the outer wall  
32 of the inner pipe and will be in sealing

1 contact with each of said inner and said outer  
2 walls.

3

4 14 A seal assembly according to any one of claims  
5 1 to 3 wherein

6 (a) the annular member is dimensioned so that  
7 it will be sealing contact with only one  
8 of the inner wall of the outer pipe and  
9 the outer wall of the inner pipe and will  
10 provide an opening in said annular space  
11 between the annular member and the wall  
12 with which it is not in sealing contact;  
13 and

14 (b) the moveable blocking means comprises  
15 resilient means which is deformable under  
16 the pressure of liquid flow in the annular  
17 space to close said opening.

18

19 15 A seal assembly according to claim 14 wherein  
20 the annular member has a longitudinal end face  
21 which has a recess to define upper and lower  
22 arms and one of these arms is the resilient  
23 means deformable under the pressure of liquid  
24 flow in the annular space to close said  
25 opening.

26

27 16 A seal assembly according to claim 13 or claim  
28 14 which comprises annular restraining means  
29 bonded to the upper and lower arms of the  
30 annular member.

31

1     17     A pipe system comprising an inner and an outer  
2             pipe and a seal assembly according to any one  
3             of the preceding claims.

4

5     18     A valve suitable for use in the seal assembly  
6             of any one of claims 7 to 12.

7

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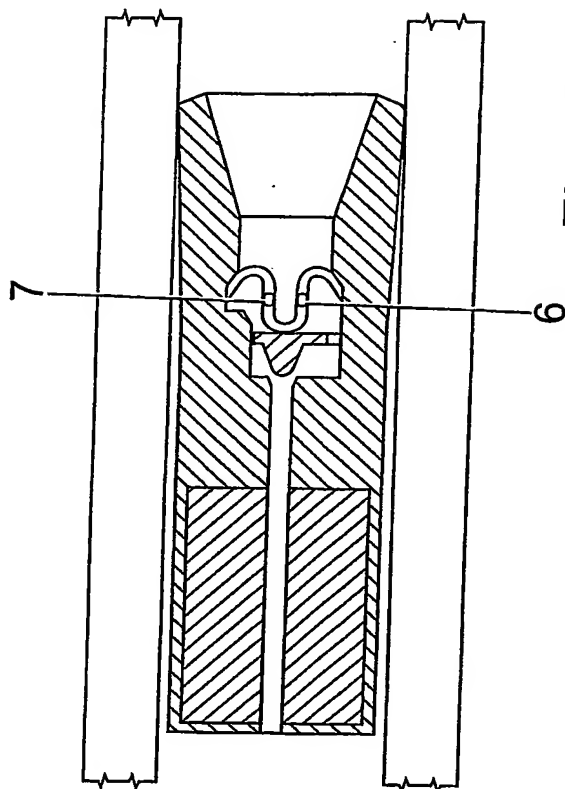


Fig. 1b

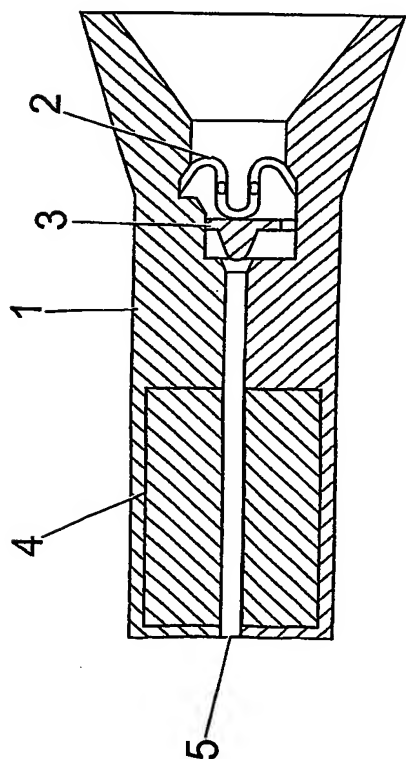


Fig. 1a

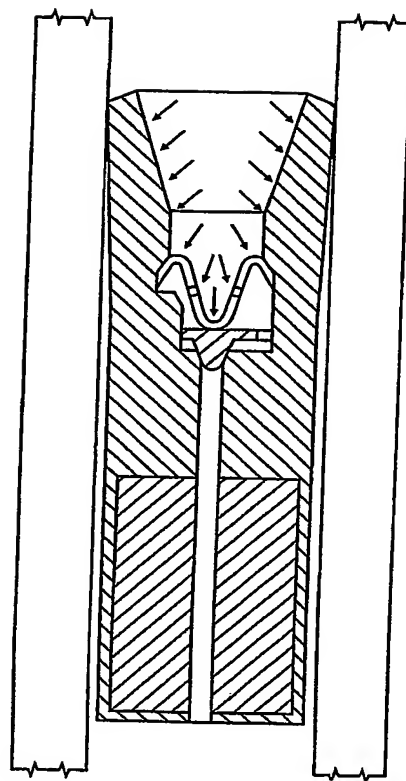


Fig. 1c

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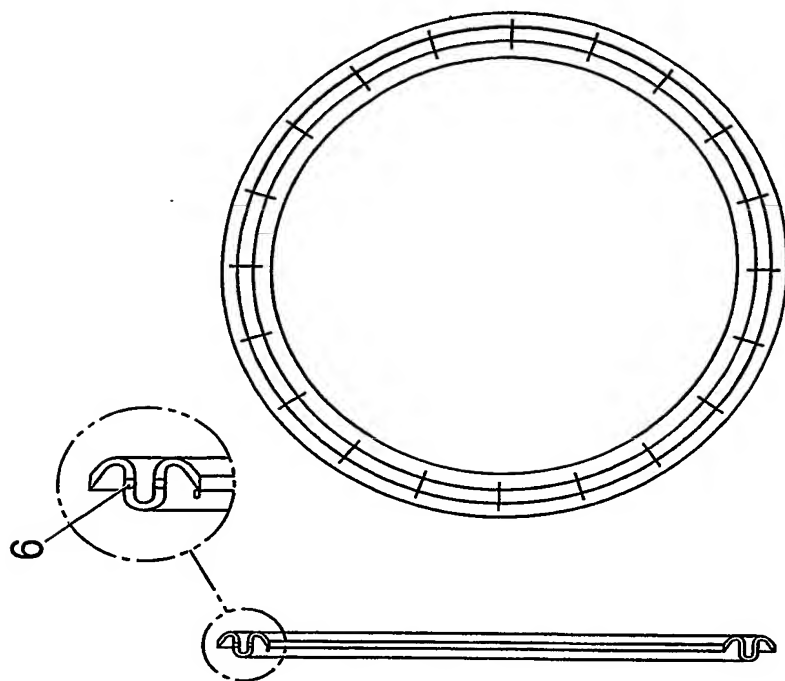


Fig. 1e

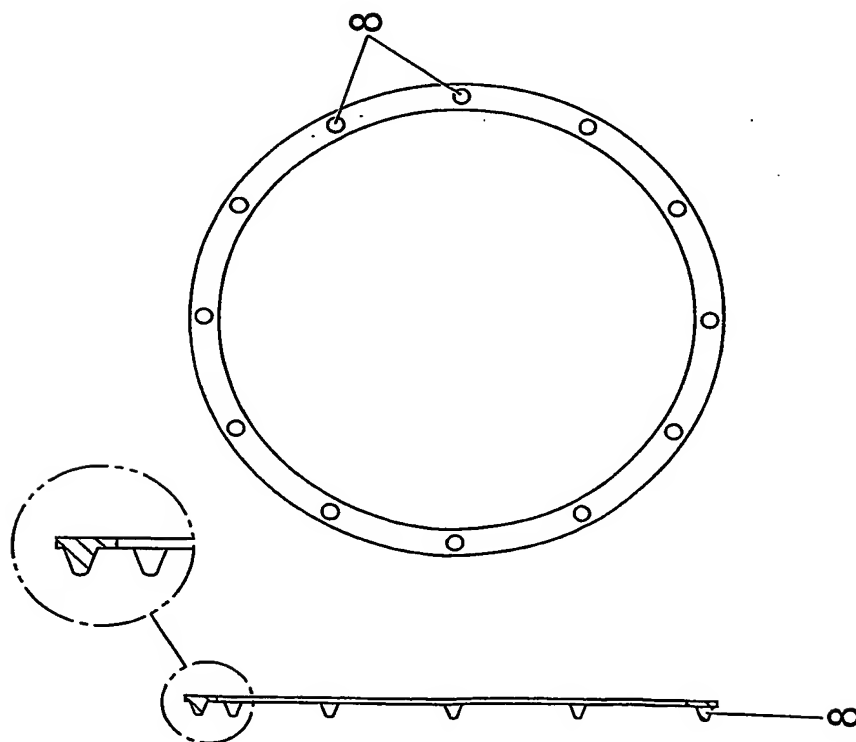
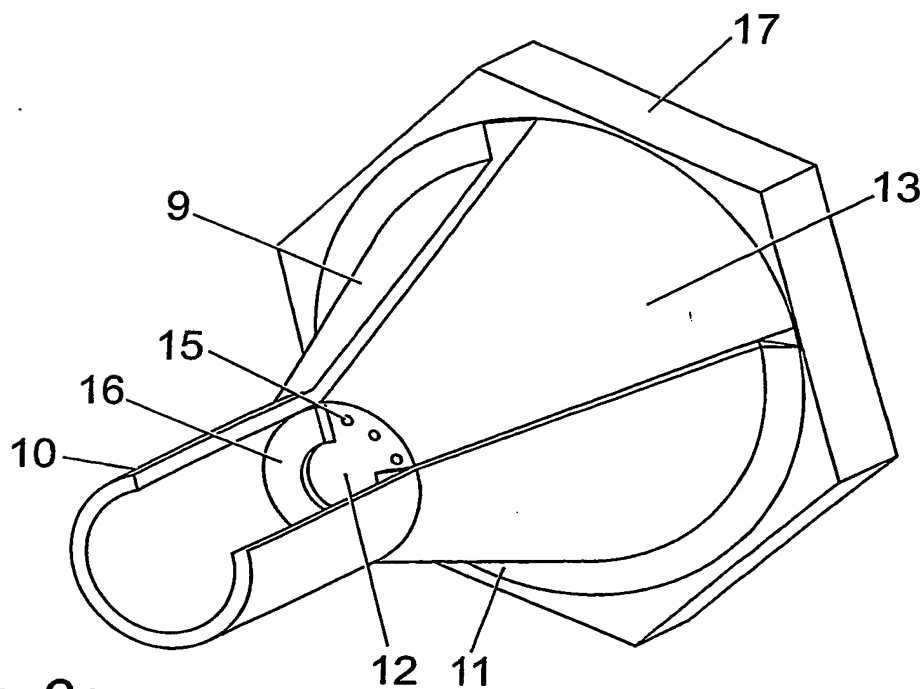
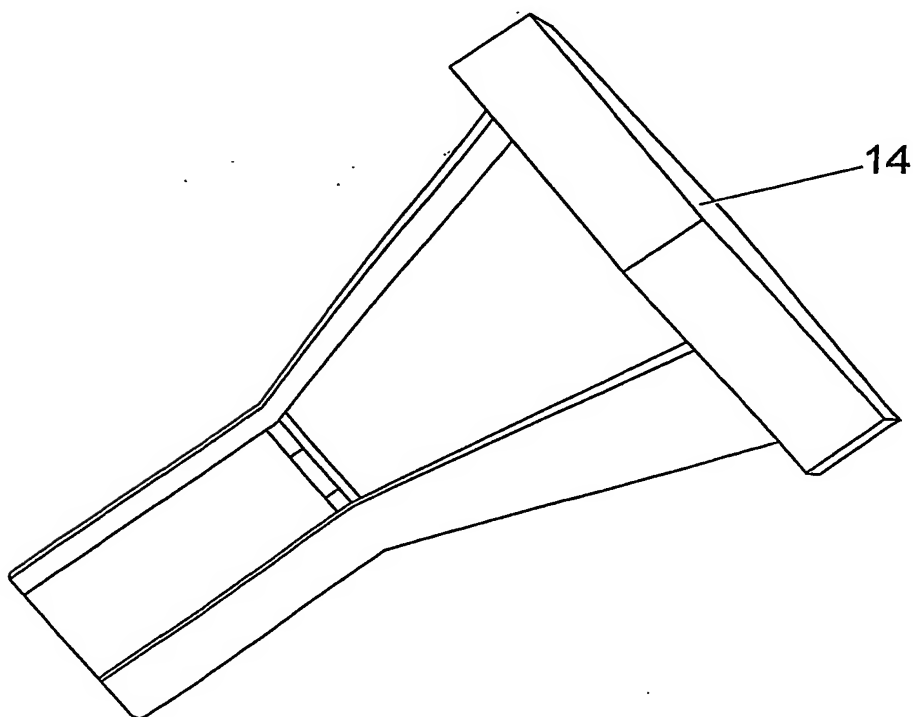


Fig. 1d

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*Fig. 2a*



*Fig. 2b*

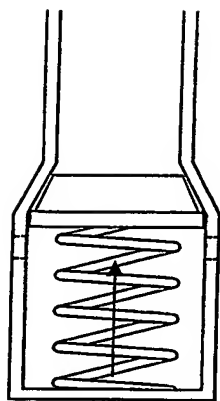


Fig. 3b

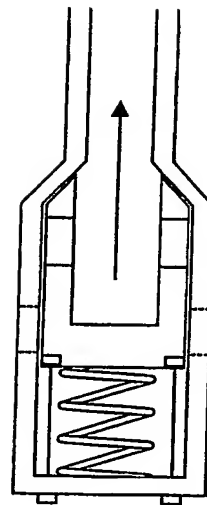


Fig. 3d

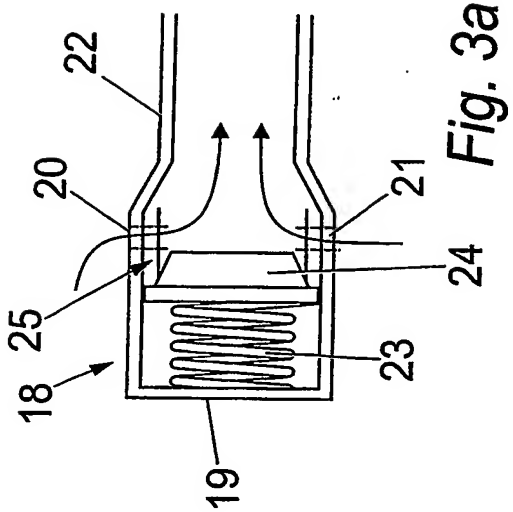


Fig. 3a

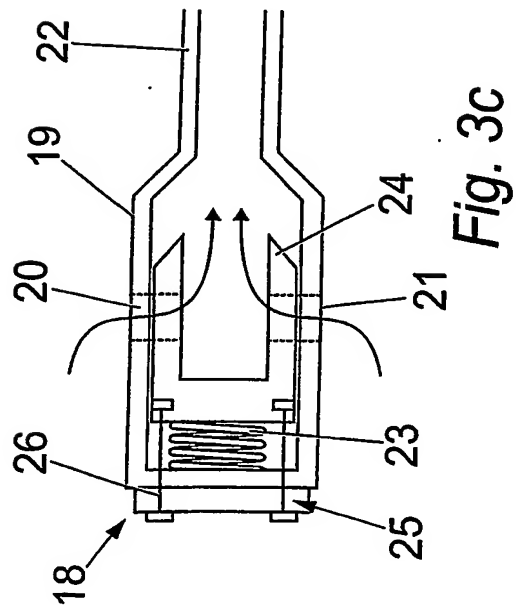
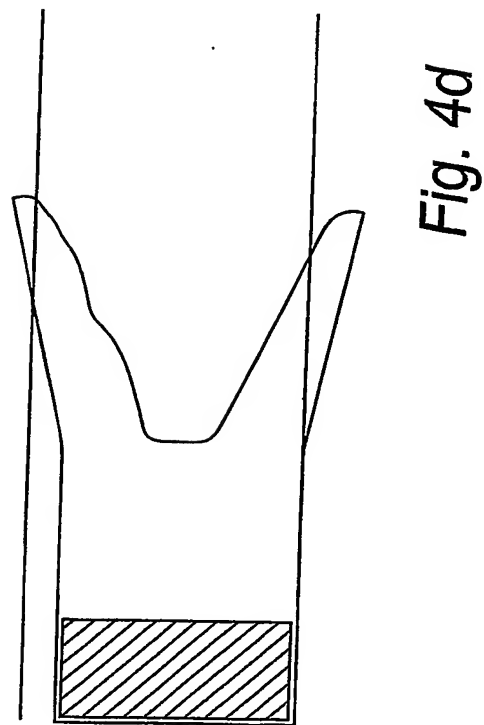
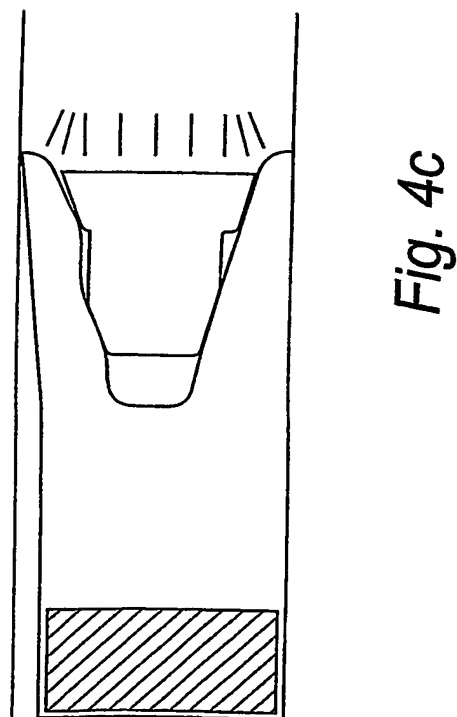
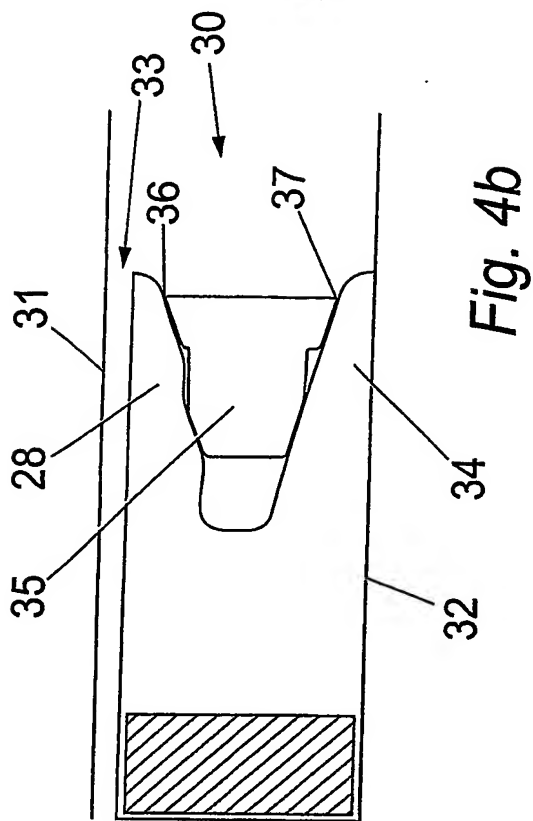
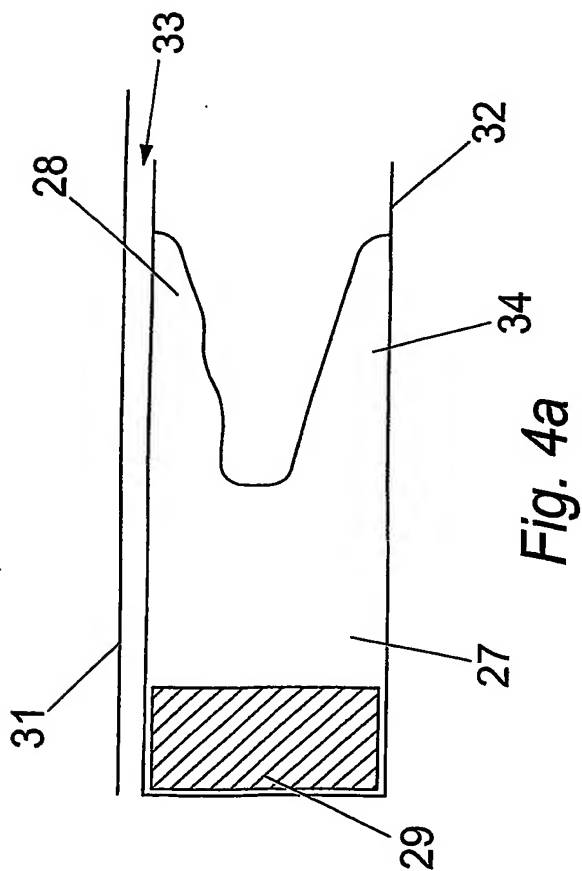


Fig. 3c



# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/03/08115

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F16L7/02

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F16L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	TOUGH G ET AL: "INNOVATIONS KEY REELED PIPE-IN-PIPE FLOWLINE FOR GULF DEEPWATER PROJECT" OIL AND GAS JOURNAL, PENNWELL PUBLISHING CO. TULSA, US, vol. 99, no. 33, 13 August 2001 (2001-08-13), pages 46-52, XP001112016 ISSN: 0030-1388	1-3, 13-15, 17
A	page 50 -page 51; figures 8,10 ---	16
X	GB 2 317 934 A (REGAL RUBBER COMPANY LIMITED) 8 April 1998 (1998-04-08) cited in the application abstract; figure 4 -----	1

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Further documents are listed in the continuation of box C.

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Patent family members are listed in annex.

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Date of the actual completion of the international search

27 October 2003

Date of mailing of the international search report

05/11/2003

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Authorized officer

Vecchio, G

### Information on patent family members

PCT/03/08115

Patent document  
cited in search report

Publication date

Patent family member(s)

Publication date

GB 2317934

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08-04-1998

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